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# APANTELES MELANOSCELUS, AN IMPORTED PARASITE OF THE GIPSY MOTH.

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## INTRODUCTION.

From the year 1905 to December 1, 1911, the State of Massachusetts and the Bureau of Entomology, United States Department of Agriculture, shared the expenses involved in carrying on an investigation of the natural insect enemies of the gipsy moth (*Porthetria dispar* L.) and the brown-tail moth (*Euproctis chrysorrhoea* L.) in Europe and of the introduction of parasites of these insects from

[1] The writer wishes to acknowledge the efforts of all those who have been connected with the Gipsy Moth Laboratory during the period covered by this report, who have assisted at various times in gathering and recording some of the data from which this bulletin has been prepared. H. A. Preston and C. E. Hood took most of the photographs and W. N. Dovener made the drawing of the adult Apanteles. He wishes especially at this time to express his appreciation and thanks to A. F. Burgess, who has general direction of the work, for his help and suggestions.

their native homes to New England. A comprehensive report[2] of this work from its beginnings through 1910 has been published in Bulletin 91 of the Bureau of Entomology.

Among the imported parasites which are now established is *Apanteles melanoscelus* Ratz., a double-brooded parasite of the gipsy moth. The following report has been prepared in two parts: Part I contains the description of the species and its life history, and Part II takes up its introduction and establishment.

## PART I.—DESCRIPTION AND LIFE HISTORY.

### HISTORY.

The insect was described by Ratzeburg[3] in 1844 very briefly as follows (translation):

*Microgaster melanoscelus* is so similar to *solitarius* that, since it also has the same mode of life, one might regard it as merely a variety of that species; but it is distinguished not only by the very black femora. . . but also by the third abdominal segment being scarcely rugose, only coarsely punctate at base. Pits at the base of the scutel very narrow. The one male which I possess is only one line long.

In 1852 Ratzeburg[4] again mentions this species and gives a record of its being reared from *Porthetria dispar* L. and *Stilpnotia salicis* L.

Reinhard[5] writes in 1880 as follows:

The specimens called by Ratzeburg (Ich. der Forstinsect. III) *Apanteles melanoscelus*, bred from *Liparis salicis*, are beyond all doubt this species.

Reinhard is here speaking of *A. solitarius* and believes the two to be synonymous. In the same article he places Ratzeburg's type of *A. melanoscelus* in *A. difficilis* (Nees) Reinh. This is undoubtedly incorrect, as the biology of the two parasites is very different.

Marshall[6] writes in part as follows of *A. difficilis:*

Common. The cocoons are flesh-colored or buff . . .; a few, by some accident, are more yellow. The maggots, on leaving the body of their victim, make separate naked cases, without clustering together. From 1 to 20 issue from a single caterpillar, according to its size.

Dalla Torre[7] in 1898 also considered *melanoscelus* synonymous with *A. difficilis* (Nees) Reinh.

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[2] HOWARD, L. O., and FISKE, W. F. THE IMPORTATION INTO THE UNITED STATES OF THE PARASITES OF THE GIPSY MOTH AND THE BROWN-TAIL MOTH. U. S. Dept. Agr. Bur. Ent. Bul. 91. 344 p., 74 figs., 27 pl. (1 col.). 1911.

[3] RATZEBURG, JULIUS THEODOR CHRISTIAN. DIE ICHNEUMONEN DER FORSTINSECTEN, v. 1, p. 74, no. 21. 1844.

[4] RATZEBURG, JULIUS THEODOR CHRISTIAN. DIE ICHNEUMONEN DER FORSTINSECTEN, v. 3, p. 56, no. 51. 1852.

[5] REINHARD, H. BEITRÄGE ZUR KENNTNIS EINIGER BRACONIDEN-GATTUNGEN. *In* Deutsche Ent. Zeitschr., jhrg. 24, heft 2, p. 352–370. 1880.

[6] MARSHALL, T. A. MONOGRAPH OF BRITISH BRACONIDAE, Pt. 1. *In* Trans. Ent. Soc. London, 1885, p. 163.

[7] DALLA TORRE, C. G. DE. CATALOGUS HYMENOPTERORUM, v. 4, BRACONIDAE, p. 168. 1898.

### DISTRIBUTION IN EUROPE.

*Apanteles melanoscelus* is probably present over most of Europe. Specimens have been received at the Gipsy Moth Laboratory from Vienna, Austria; Sicily, Italy; Bendery, Russia; and from Saxony, Brandenburg, Pomerania, and Rhenish Prussia, Germany.

### DESCRIPTION OF SPECIES.

It is evident that *solitarius* and *melanoscelus* are closely related, and in time it may be shown that they are the same. If such should prove to be the case, the name *melanoscelus* would have to go, as *solitarius* has the priority. For the present they are to be considered as distinct species, and as Ratzeburg's[8] description of *A. melanoscelus* is very meager, the following new description has been prepared.[9]

#### FEMALE.

Length 3 mm. Face feebly shagreened and strongly shiny, with a weak median welt below insertion of antennæ; vertex, temples, and cheeks shagreened, pilose, shiny; mesoscutum shallowly, sometimes indistinctly punctate and shiny; scutellum with the disk very slightly convex, smooth, and polished; mesopleuræ smooth and highly polished, with only a few punctures anteriorly and below, and a conspicuous weakly crenulate depression posteriorly; propodeum rugose except at base, strongly shiny, and with a prominent median longitudinal carina; forewing with stigma large and with the radius very distinctly longer than the transverse cubitus; posterior coxæ large, smooth, and shiny, with a conspicuous flattened area on outer edge at base; spurs of posterior tibiæ equal in length and about half as long as the metatarsus. Abdomen stout; entirely shiny; first tergite broader at apex than at base, rugose punctate; second broad, rectangular, more or less roughened, without distinct lateral membranous margins; third tergite with the rugosity usually confined to the extreme base; remainder of abdomen polished; ovipositor hardly exserted; hypopygium not extending beyond apex of last dorsal segment. Black; antennæ entirely black; tegulæ black; wings hyaline, the stigma dark brown; all coxæ and trochanters black, except sometimes apex of the latter; base of fore femora usually, basal half of middle femora, and most of the posterior femora black or blackish; apical fourth of hind tibiæ and the hind tarsi dusky; sides and venter of the abdomen black. (Pl. I, A.)

#### MALE.

Essentially as in the female. Differs only in the longer antennæ, in the usually darker legs, and in the basal abdominal tergites being less roughened.

The species is exceedingly close to *A. solitarius* Ratzeburg, but apparently the differences are sufficiently well marked and sufficiently constant to justify holding the two forms distinct. In *A. solitarius* the antennæ are brownish testaceous toward base, the legs, with the exception of the coxæ and the basal trochanters, are practically en-

[8] RATZEBURG, JULIUS THEODOR CHRISTIAN. OP. CIT. 1844.

[9] The description and translations of references Nos. 3 and 5 were made by Mr. C. F. W. Muesebeck.

tirely stramineous, and the three basal abdominal tergites are more coarsely rugose, the roughening on the third tergite extending well toward the posterior margin medially; the narrow lateral membranous margins on the apical fourth of the first abdominal tergite are testaceous in *A. solitarius*, while they are piceous black in *A. melanoscelus*.

### METHODS USED IN BIOLOGICAL WORK.

As this species hibernates as a maggot within its cocoon, it is a simple matter to gather material during the fall and winter for study in the spring. The cocoons were kept in the laboratory yard during the winter, in cylindrical cages 3 by 8 inches, made of very fine copper netting. Occasionally during the winter a few cocoons were dissected to ascertain the condition of the maggots and to note any changes which might have taken place. As spring approached, the cocoons were isolated, being placed in small gelatin capsules, or small glass vials 1½ inches by ½ inch. It is necessary to isolate each of the cocoons at this time of the year for two reasons: First, so that one may know the exact age of the adults with which he is working and keep the males and females separate; second, to prevent any secondary parasites which may issue from the cocoons during the spring from ruining the rest of the Apanteles material.

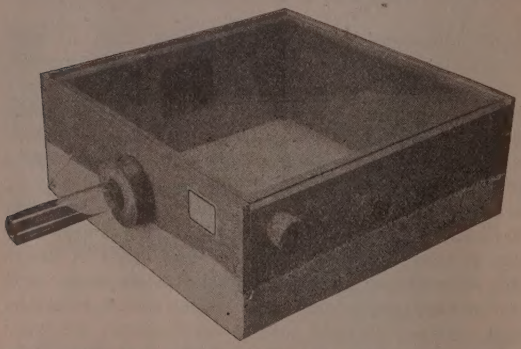


FIG. 1.—Tray with glass top used in life-history experiments with *Apanteles melanoscelus*. (After Culver.)

As soon as the Apanteles issued they were removed from their containers and placed in glass tubes or glass-covered trays (fig. 1), where they were fed a mixture of equal parts of water and honey. A convenient method of feeding is to dampen a small piece of clean sponge with the food and place it in the tube or tray containing the Apanteles. The sponge should be washed out every day or so and dampened again with a fresh mixture of honey and water.

Parasite-free gipsy-moth larvæ were obtained by rearing them from eggs, and a supply was kept in trays protected from parasites ready for use at all times.

Two sizes of glass tubes were found convenient, a small one 4 inches by 1 inch for isolated individuals, and a larger size, 8 by 2

inches, for confining several. As the Apanteles are usually active and soon exhaust themselves if allowed to remain in the light, the tubes or cages containing them were kept dark when not in use.

Records of oviposition were obtained in the following manner: A glass tube containing a single female was brought into the light and a parasite-free gipsy-moth larva was introduced on the point of a small camel's-hair brush. As soon as the parasite oviposited in the caterpillar, the larva was removed to a can for rearing. This procedure was continued as long as a female would oviposit readily. As soon as she began to show a lack of interest in the gipsy-moth larvæ, she was returned to the dark to rest and a fresh female given an opportunity to oviposit.

After the first female had rested for an hour or two she was again brought into the light and presented with gipsy-moth larvæ as before. This process was continued with several females throughout their life.

The parasitized larvæ were kept isolated in cylindrical cans, which measured 2½ by 2 inches, there fed, and kept for future study. The structure and length of the various larval instars were determined by daily dissections of these parasitized caterpillars.

### LIFE HISTORY.

*Apanteles melanoscelus* hibernates as a third-stage maggot within its tough sulphur-yellow cocoon. Under field conditions the adults emerge from their cocoons over a period of about three weeks. Emergence is at its height when the gipsy-moth egg hatching is at its maximum, usually during the second week in May. The period of emergence of adults from cocoons kept at the laboratory where all of the cocoons are held under the same conditions is five or six days. The majority of the males emerge during the first four days; the females, beginning to emerge on the second day, continue emerging for four or five days, the bulk of emergence being on the third day after the first appearance of either sex. The adult escapes through a circular hole which it cuts at the anterior end of the cocoon.

Females of *A. melanoscelus* are ready for mating or for oviposition within two or three hours after issuing. They oviposit just as freely whether they have been fertilized or not, and, as is the case with many parasitic Hymenoptera, they often reproduce parthenogenetically.

This species does not copulate readily when enclosed in glass vials or small cages, but was often observed in coition in the large breeding chamber (Pl. V, C). The male approaches the female in the usual state of excitement with its antennæ and wings constantly vibrating. The act of copulation is a matter of a few seconds.

### Oviposition.

The act of oviposition takes about one second. The female may alight upon a gipsy-moth larva from flight or walk up to one. In either case the ovipositor is inserted and withdrawn very quickly and practically always an individual egg is deposited. Many larvæ have been dissected after apparent oviposition had been observed and in no case has more than one egg been found from a single oviposition and only rarely have dissections been made which failed to show the presence of an egg. Often the larva attacked thrashes about so violently that it and the parasite fall, but rarely does the parasite fail in its object. After ovipositing in a larva the female usually proceeds to another victim, but occasionally will oviposit a second time before leaving the caterpillar. She apparently does not examine a prospective host but attacks it whether it has previously been parasitized or not. This practice of occasionally placing an egg in a parasitized caterpillar is unfortunate as only very exceptionally will more than one maggot develop within a single host. The parasite favors the posterior half of the caterpillar for oviposition, but will oviposit in any segment of the body.

The females of *A. melanoscelus* which issue from hibernating cocoons prefer to parasitize the first and second stage gipsy-moth larvæ but will oviposit successfully in third-stage larvæ if they are present. When the next or summer generation of adults appear, most of the gipsy-moth larvæ are in the third stage. This is the stage most heavily attacked by this generation, although many fourth-stage caterpillars are successfully parasitized. Apanteles females of this generation often attempt oviposition in fifth and sixth stage larvæ but are not so successful, for they are hindered by the long hairs of large larvæ.

There was considerable variation in the number of ovipositions different individuals would make. Between 200 and 300 ovipositions per female were often obtained in these experiments. The greatest number of ovipositions secured by a single female of *A. melanoscelus* was 535. She actually had gipsy-moth larvæ before her for 510 minutes, making these ovipositions a little faster than one a minute.[10] The parasite was allowed several oviposition periods each day and she would parasitize the gipsy-moth larvæ as fast as they were introduced for from 30 to 60 minutes. The first day the periods of oviposition were a little longer than during the following days. This female issued May 23 from its hibernating cocoon, but was not given an opportunity to oviposit until May 27, when

[10] This is about as fast as larvæ can be introduced and withdrawn by the process used. Under more natural conditions, as found in the large breeding chamber, the females were often observed to oviposit 6 or 7 times a minute.

the first gipsy-moth larva was introduced. She worked actively every time she was allowed to do so each day to and including June 2. On the morning of June 3 she was found dead in the tube. A dissection showed that her ovaries still contained about 150 mature eggs and about 200 eggs in different stages of development.

From this and other records, together with notes made from dissections of mature females of *A. melanoscelus*, it seems safe to assume that under natural conditions each female is capable of depositing in the vicinity of 1,000 eggs.

### Egg.

The egg at time of deposition averages 0.55 mm. in length and 0.1 mm. in width. It (Pl. I, B) is deposited singly in the body cavity just beneath the skin of the host. It is transparent, with the cephalic end rounded, the caudal end, which is slightly narrowed, bearing a short stock. The chorion appears to be entirely without ornamentation. Development within the egg is rapid and the embryo begins to show form after 15 to 20 hours (Pl. I, C). By this time the egg has widened a little and is slightly shorter than when first deposited. Many eggs have hatched 48 hours after deposition. Just before hatching, the fully developed embryo is plainly seen, often in the position illustrated in Plate I, D. At this time the egg measures 0.7 mm. in length and is greatly swollen around the area which incloses the head. On one occasion an egg, which was ready to hatch, burst while under observation and the larva floated out as illustrated in Plate I, E, after which the eggshell shriveled up considerably.

The length of the egg stage is from 48 to 72 hours, depending on the temperature. If the weather is warm, the majority of the eggs hatch in about two days.

### Larva.

#### FIRST-STAGE LARVA.

The following measurements are the average for newly-hatched larvæ: Total length, 0.7 mm.; width of head, 0.2 mm.; width of body, 0.1 mm.; length of caudal horn, 0.1 mm.

The freshly-hatched larva (Pl. I, F) is found free in the body cavity. Directly after hatching it may be found in almost any part of the cavity, depending on the point of deposition of the egg. After a few hours it works its way to the dorsal part of the posterior third of the host and usually remains in that area until about ready to issue as a third-stage maggot.

The larva is transparent and extremely delicate, with a large head which is twice the width of the body. The head is composed of a single segment. The labium, labrum, and maxillæ are present. The

sickle-shaped mandibles (Pl. I, J), which are well fitted for tearing, are plainly seen, being in motion much of the time, as the maggot feeds on the lymph and fat bodies of its host. They are 0.08 mm. long, are chitinized throughout, but more heavily so at the tips, and form a good character for distinguishing this stage from the following ones. The body is made up of ten segments at this period, but later has eleven after the tenth segment divides. On the dorsum the maggot has a systematic arrangement of short, rather stiff, backward pointing spines. The spines are located as follows: Two each on the second and third segments, four on the fourth segment, six each on the fifth to ninth segments inclusive, and eight on the tenth segment. It seems likely that these spines assist the maggot in working its way to the caudal end of the host.

The anal vesicle, which is common to the microgasterine larvæ, is prominent and the caudal horn is seen just beneath the evaginated anal vesicle.

As the larva matures, the heart, nervous system, and silk glands can be distinguished, but no evidence of the tracheal system is apparent.

When ready to molt the larva has increased in length to nearly 2 mm. and the body has widened in proportion, except the head, which remains about the same width throughout the stage.

The larva remains in this stage from two to three days in the spring generation and from six to eight days in the summer generation.

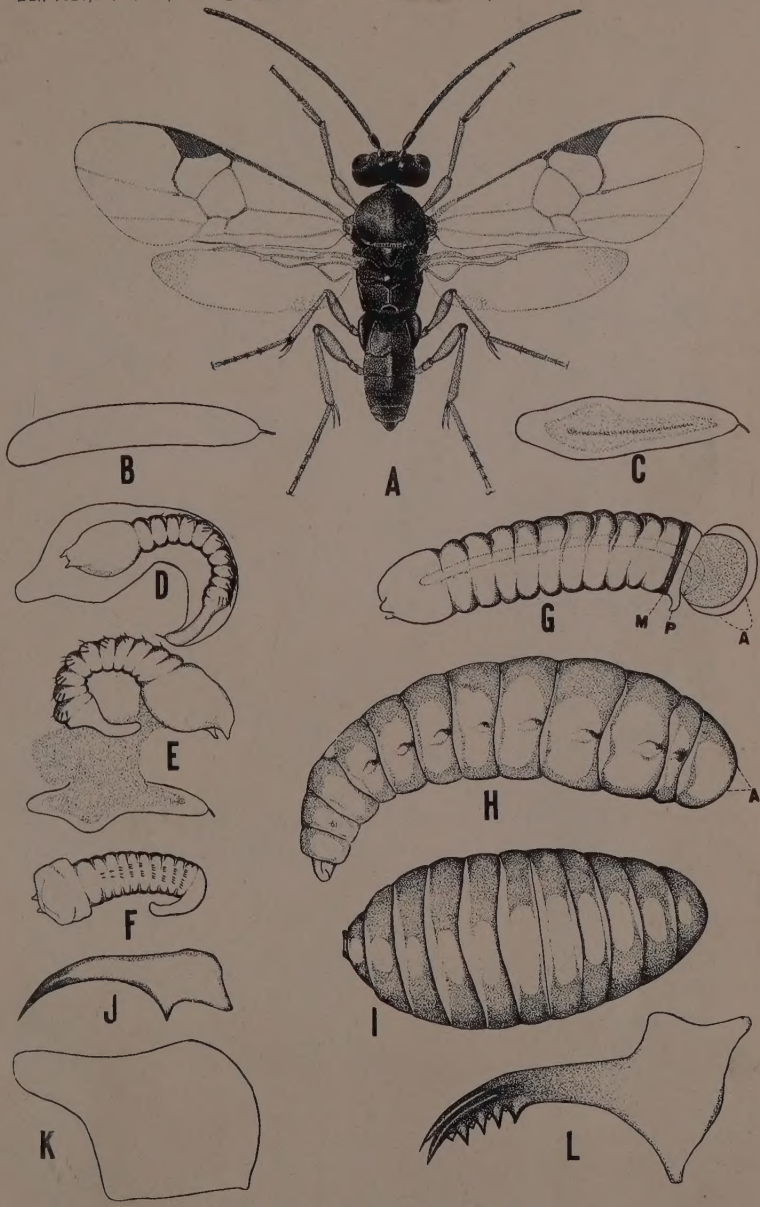
### SECOND-STAGE LARVA.

In molting the head skin of the first-stage maggot is split off and is occasionally found in the body cavity of the host, closely associated with the cephalic region of the second-stage larva. The remainder of the molt skin is worked back to the last body segment (Pl. I, G at M).

The second-stage maggot is usually found dorsally in the caudal end of the host in the body cavity, its head toward the posterior end of the caterpillar and its body resting longitudinally. When first molted it measures about 2.75 mm. in length and 0.55 mm. in width, the head and body being approximately the same width.

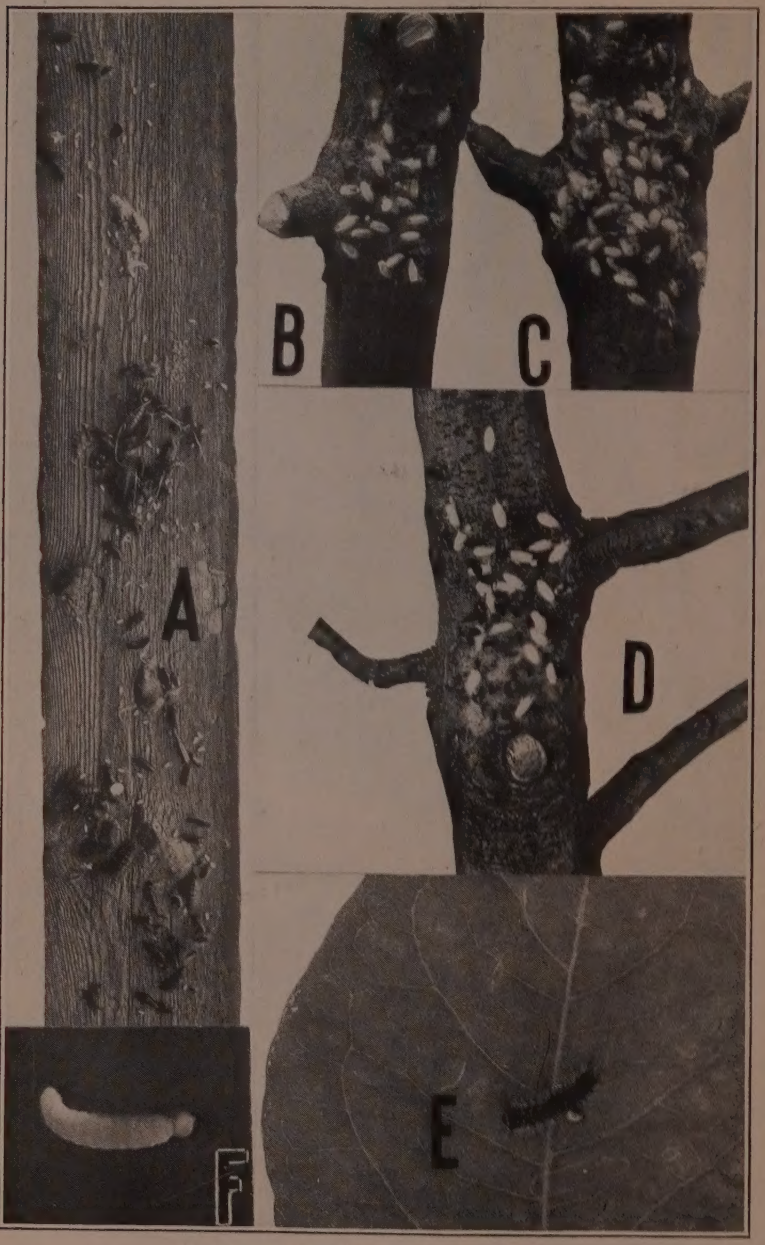
In contrast to the first-stage maggot the body is entirely destitute of spines and the mouthparts are poorly developed. The mandibles (Pl. I, K) are not fitted for tearing or biting, but are soft, fleshy forms without chitin and are very difficult to locate.

The anal vesicle is still present and is more prominent than in the previous stage (Pl. I, G at A). The caudal horn is present but has not grown with the developing maggot and appears very small in comparison with the size of the larva (Pl. I, G at P).




## APANTELES MELANOSCELUS.

*A*, adult female; *B*, egg, dissected from female; *C*, egg, after 15 to 20 hours in host; *D*, egg, after 48 hours in host; *E*, first-stage larva and shriveled eggshell from which it came, 50 hours after oviposition; *F*, first-stage larva; *G*, second-stage larva; *m*, molted skin, *p*, caudal horn, *a*, anal vesicle; *H*, third-stage larva, dissected from host; *a*, anal vesicle; *I*, third-stage larva, hibernating form, dissected from cocoon; *J*, first-stage larval mandible; *K*, second-stage larval mandible; *L*, third-stage larval mandible. All much enlarged.




## APANTELES MELANOSCELUS.

*A*, Hibernating cocoons on board found in Melrose, Mass., 1917; *B*, first-generation cocoons on branch collected at Quincy, Mass., 1920; *C*, first-generation cocoons on branch collected at Melrose, Mass., 1916; *D*, first-generation cocoons on branch collected at Quincy, Mass., 1920; *E*, third-stage maggot two-thirds of its way out of fourth-stage gipsy-moth larva; *F*, third-stage maggot dissected from host, anal vesicle still evaginated.

APANTELES MELANOSCELUS.

*A*, Hibernating cocoons on underside of vessel collected at Weymouth, Mass., 1920; *B*, hibernating cocoons on underside of bark collected at West Boylston, Mass., 1920; *C*, hibernating cocoons on underside of branch collected at Hingham, Mass., 1920; *D*, hibernating cocoons on stump collected at Melrose, Mass., 1916.

The heart, nervous system, and silk glands are more pronounced, especially the latter, which are coiled and recoiled and appear to fill much of the body cavity. Traces of the tracheal system are observed during the last part of the stage.

Development is rapid and in two or three days the maggot has increased in size to 4.5 mm. long and 1 mm. wide.

The average period spent in this stage by the first-generation larva is from two to three days and for the second generation from five to seven days. Just before molting the mandibles of the third-stage maggot can be seen.

THIRD-STAGE LARVA.

The period spent by the third-stage maggot (Pl. I, H) within its host varies from a few hours to two days with the spring generation and as long as three days with the summer generation. When a second-stage maggot is about ready to molt it usually works its way to the central part of its host and molts there, although occasionally third-stage larvæ are found in the caudal end of the caterpillar. Just before issuing the maggot is 5 to 7 mm. long, is slender, and tapers toward the anterior end; it is dull white and dorsally is sparsely covered with very fine, inconspicuous hairs. At the caudal end of the body the anal vesicle is still evaginated (Pl. I, H at A; Pl. II, F). The body is apparently filled with the silk glands and has a well-developed tracheal system, with eight pairs of spiracles visible. There is a pair on the second segment and a pair on each of segments 4 to 10, inclusive. The spiracles are very tiny and difficult to determine, the last seven pairs being associated with laterally protruding areas. On the eleventh segment there is a slight protruding area laterally which may contain a spiracle, but one was not observed on this segment. The mouthparts are plainly visible, consisting of labium, labial palpi, labrum, maxillæ, maxillary palpi, and mandibles. The mandibles (Pl. I, L), which are 0.26 mm. long, are strong and well fitted for tearing. They are slightly curved anteriorly. The tip is divided into two sharp teeth. The anterior third of the mandible appears to be double with two biting edges, each edge armed with several teeth. There are dorsally on this part of the mandible two elevations which appear to strengthen the organ. The tips and points of the teeth are more heavily chitinized than the rest of the mandible.

When ready to issue the maggot tears a hole in the side of the caterpillar, usually in the fifth or sixth segment. When it has issued to about two-thirds its length it begins to form its cocoon (Pl. II, E). By the time the larva is entirely out, the anal vesicle has been invaginated. If the larva is of the spring generation, it voids the accumulated waste material of the larval stages after 18 to 20 hours in the cocoon. In about two days after completion of the

cocoon the maggot pupates and casts its larval skin, which is pushed back to the posterior end of the cocoon over the previously voided material.

The third-stage maggot (Pl. I, I) of the summer generation has quite a different cycle. After having completed its cocoon, in which it is to hibernate, it becomes shorter and stouter, measuring about 4 mm. in length. It is a pale lemon yellow, and remains quiescent until the following spring. About the time when the first gipsy moth eggs hatch, the maggot resumes activity, first voiding the accumulated waste in the caudal end of the cocoon. Two or three days later pupation takes place, and the larval skin is cast and pushed to the caudal end of the cocoon, as in the spring generation.

### Pupa.

The pupal stage lasts from five to nine days. About two days after the completion of the cocoon the larval skin is cast. The pupa is whitish with long appendages and has a movable abdomen. The eyes soon begin to darken, the ocelli are distinguishable, and the thoracic and abdominal segments take form. The mouth parts, antennæ, legs, and recurved ovipositor are plainly seen. In three or more days the development is complete. The whole is now dark, nearly black. The pupal skin is cast and the adult lifts the cocoon cap, having cut around its base, which was left weak by the spinning larva.

### Cocoon.

When the third-stage maggot is about two-thirds of its way out of the host, it begins to construct its cocoon. The first few threads seem to be attached ventrally to the maggot itself on the last segment which is outside of the caterpillar. After making an attachment at this point the maggot straightens out horizontally, then swings back underneath itself again and makes another attachment. It continues this process laterally and dorsally, spinning all the while and forming loops which it gradually fastens securely in a similar manner. As the outer loose cocoon is developed, the maggot must break away from the original attachments and gradually work itself entirely free from its host. The maggot reverses its position several times during the construction of the cocoon. When completed, the cocoon is about 5mm. long and is composed of an outer loose covering of fine threads, some of which are attached to the host or any object on which it may rest. Just within this is a tough, tightly woven envelope, which encases a very fine smooth inner sac next to the maggot. The cocoon is slightly flattened on its ventral surface and convex laterally and dorsally. The anterior end is rather flat. The cap, which is thinner along its base, is at the anterior end. The posterior end is slightly pointed. It takes the spring-

generation maggot about two hours to form its cocoon and the summer maggot three to four hours to complete the cocoon in which it is to hibernate.

The cocoon made by the spring-generation maggot is pale yellowish white, a little smaller and rather delicate as compared with the hibernating cocoon, which is a light sulphur yellow and very tough.

### LOCATION OF COCOONS.

The cocoons of the spring generation are found singly or in clusters, depending upon the degree of gipsy moth infestation and the abundance of Apanteles. In low growth the cocoons are very apt to be found on the foliage and often on the débris on the ground, as well as along the trunk and small branches. On large trees a few cocoons are found on the foliage, but if abundant the majority are located at the junction of the smaller branches on the underside. The cocoons are attached lightly, often on top of others and invariably a dead second-stage gipsy moth larva is found with each cocoon (Pl. II, B, C, D). After the adults have issued these cocoons are easily washed or blown from the trees and are seldom found the next spring.

The second-generation cocoons are found securely attached scatteringly over the tree trunk and in clusters under the larger limbs where the gipsy-moth larvæ congregate. These cocoons are not often found on the foliage.

The gipsy-moth larvæ, when parasitized by the second generation of *Apanteles melanoscelus*, have a tendency to crawl to protected and out-of-the-way places just before the issuance of the parasite maggots. The cocoons are often associated with the gipsy-moth pupæ and larger caterpillars. They are found behind billboards and signs, attached to trees (Pl. III, D), on the undersides of boards on the ground (Pl. II, A), under fence rails or rocks, under loose bark, and on rough surfaces on the underside of limbs (Pl. III, B, C). Plate III, A, shows a tin vessel found during the summer of 1920 in a dump at Weymouth, Mass., and illustrates the habit of parasitized larvæ of crawling to hidden places. There are a few over 100 cocoons on the bottom of this vessel, and there is a cluster of 25 cocoons on one side of the vessel not shown in the photograph.

### SEASONAL HISTORY.

The seasonal history varies considerably with the season. The issuance of adults of *Apanteles melanoscelus* from their hibernating cocoons begins about the time of maximum hatch of the gipsy-moth eggs, which is usually near the middle of the second week in May. During such a season most of the Apanteles will have issued by May 20. Under field conditions females of *Apanteles melanoscelus* do not

begin to oviposit immediately, for the bulk of issuance of the spring generation parasite maggots is around June 12. The adults which develop from these maggots will be found issuing from 7 to 11 days later. Cocoons of the second generation, or those in which the parasite is to pass the winter, begin to appear about the fourth of July, but usually not in abundance until the second week in July.

### FEEDING OF PARASITIZED LARVÆ VERSUS NONPARASITIZED LARVÆ.

Several feeding records were kept of gipsy-moth larvæ which were known to be parasite-free as checks against similar feeding records of larvæ in which *A. melanoscelus* had oviposited. The records show that healthy gipsy-moth larvæ eat from two to three times as much as those which contain parasite maggots. These data were obtained from feeding records made during the period between oviposition in the caterpillar and issuance of the parasite maggot and the checks were kept only for a similar number of days. The gipsy-moth larva from which a maggot of *A. melanoscelus* has issued eats no more, although it may live a few hours or as long as two weeks, the average being seven days.

### LONGEVITY EXPERIMENTS.

The tray shown in figure 1 (p. 4) was found most satisfactory for the longevity experiments although glass tubes 8 by 2 inches were used successfully for small numbers of parasites.

The adults were fed on an equal mixture of honey and water, sprayed on small pieces of sponge. It is important that the sponges should be kept clean by thoroughly washing every other day. Nothing but the food was inclosed in the trays with the adults, but in the tubes they did better if a crumpled bit of paper was present on which the parasites might rest and clean themselves. *A. melanoscelus* in the tubes and trays, if kept in the light, lived for about one week. When the containers were kept darkened by means of black paper, the parasites remained rather inactive much of the time, and lived considerably longer.

In several experiments with adults issuing in spring and summer, males and females lived for 30 to 32 days. In one case a female of the summer issuing generation lived 35 days. There was very little difference in the length of life of the adults, the females living slightly longer than the males. Without food they were able to live only a few days.

### HOSTS OF A. MELANOSCELUS.

Ratzeburg [11] gives as hosts in Europe *Porthetria dispar* L. and *Stilpnotia salicis* L.

From field-collected material in this country *A. melanoscelus* has been reared only from the gipsy moth. *S. salicis*, the satin moth.

[11] Ratzeburg, Julius Theodor Christian. op cit. 1852.

recorded as a host of this parasite in Europe, was not found in America until the latter part of June, 1920, when a heavy infestation was discovered at Medford, Mass. When the infestation was found the larvæ were from half to full grown and rather too large to be expected to harbor *A. melanoscelus* maggots. Collections of larvæ were made immediately, but no *A. melanoscelus* were reared. On several occasions, however, cocoons of this species were found on tree trunks closely associated with belated larvæ of *Stilpnotia salicis*, and there is very little doubt that these cocoons were spun by *A. melanoscelus* maggots which had issued from the near-by small and inactive larvæ of *S. salicis*. It is known that with the gipsy moth the larvæ from which *A. melanoscelus* maggots issue do not die for several days. They are rather inactive and often do not move far from the place where they were when the parasite issued.

In August, 1920, an outbreak of *Hemerocampa leucostigma* S. & A. was located in a small area in Somerville, Mass. This is the first time since *A. melanoscelus* has been established that larvæ of the white-marked tussock moth could be collected in eastern Massachusetts, except very sparingly. The season was too far advanced to expect to rear *A. melanoscelus* from collected material, and none were recovered from larvæ brought to the laboratory. It was apparent, however, from observations made at the infestation, that this parasite had been responsible for the untimely death of very many tussock-moth larvæ, for the cocoons of *A. melanoscelus* were abundant on the sheathing of near-by houses where the tussock-moth larvæ had gathered in large numbers and were spinning their cocoons.

Several experiments were tried confining adults of *A. melanoscelus* with various larvæ. Reproduction was successful with *Malacosoma americana* Fab., *M. disstria* Hübn., *Hemerocampa leucostigma* S. & A., *Olene basiflava* Pack., and *Euproctis chrysorrhoea* L. The female attacked all but the last eagerly. Oviposition apparently took place in *Charidryas nycteis* D. & H., *Hemileuca maia* Dru., *Pteronus ribesii* Scop., and in a species of tortricid. All of these larvæ died and were dissected. Several maggots of *A. melanoscelus* were found in the larvæ of *C. nycteis*, but no evidence of parasitism was found in the other larvæ.

Several larvæ of *Stilpnotia salicis* were presented to females of *A. melanoscelus*. No oviposition was recorded. This was late in the season and the larvæ had matured much beyond an attractive stage for oviposition by this parasite.

Some six or seven species of smooth-skinned or hairless larvæ have been confined with females of *A. melanoscelus* but rarely have they shown any attention to them. This parasite evidently will attack quite a number of small hairy lepidopterous larvæ when the oppor-

tunity presents itself, but shows very little interest in large hairy caterpillars or in larvæ which are destitute of hair or only sparsely covered.

## PART II.—INTRODUCTION AND ESTABLISHMENT.

### EUROPEAN WORK.[12]

In January, 1911, Mr. W. F. Fiske, who was at that time in charge of the parasite work under the direction of Dr. L. O. Howard, Chief of Bureau, sailed for Italy to investigate the parasite situation. The main object at that time was to make a study of conditions there and to attempt to introduce on a large scale *Chalcis flavipes* Panz., a pupal parasite of the gipsy moth. Headquarters were located at Naples and a vacant building was rented and fitted up for use as a laboratory near the School of Agriculture at Portici.

Early in February, 1911, Mr. Fiske visited several places in Sicily to ascertain the field conditions and degrees of gipsy moth infestation preliminary to obtaining the Chalcis material. While there he discovered that cocoons of a species of Apanteles were present in "countless thousands." This came very much as a surprise, and he determined to put most of his energies, even at the expense of previous plans, into an effort to send this parasite to America in as large numbers as possible.

The localities, a forest at San Pietro, Caltagirone, and the forests back of Barcellona, in Sicily, were situated where the gipsy-moth larvæ and cocoons were sufficiently abundant to warrant the collection of either in large numbers. Both places were some distance from a railroad, and the location which gave more promise was the less accessible of the two. As soon as the gipsy-moth larvæ had hatched and were of sufficient size to have been parasitized, collections of larvæ were begun. A foreman and crew were located at each place, and the collections of larvæ were started. The first larval collection arrived from Caltagirone at Portici on May 14, and a few cocoons were present at that time. When the collections arrived at Portici they were placed in trays in the house which was rented for that purpose. About a dozen Italian girls took care of the trays—that is, fed the caterpillars, removed the parasite cocoons daily, and kept the trays clean. These girls were very adept at this work, being familiar with the care of silkworms and having assisted in handling alfalfa weevil parasite material for shipment to America.

As soon as the cocoons were removed from the trays they were placed in cold storage to prevent the further development of the parasites.

[12] The part of this report pertaining to European work is based on the correspondence of Mr. W. F. Fiske while in Europe.

The tray work was supplemented by collections of the cocoons in the field and these had to be iced to prevent as much as possible any issuance of secondary parasites, as well as to retard the development of the maggots of *Apanteles melanoscelus*. When the cocoons arrived at Portici they were usually picked over and repacked, although it was not possible to do this in all cases.

The shipments depended largely on the supply of parasite material on hand and the dates of departure of vessels to America; but the policy followed was to ship as often as possible.

Several types of containers were used for transporting the cocoons, all of which came in the vessels' cold storage and all proved quite satisfactory. One type of refrigerator was so made that the small packages of cocoons of Apanteles in the inner chamber were entirely surrounded by ice. This refrigerator was a double-walled affair and rather expensive to construct. It was inclosed in a box of sawdust. Another type was a sort of ice-cream freezer arrangement consisting of two metal water-tight cylinders, one within the other, with the cocoons in containers packed in sawdust within the inner cylinder. Ice was packed between the two cylinders and the whole was packed in sawdust in a large wooden box. At the bottom of the outer cylinder was a small pipe which went through the box and allowed the water to drain off. On some occasions the containers were repacked with ice in New York before being forwarded to Melrose. A few shipments of cocoons which were merely packed in boxes, and kept in cold storage for as much of the trip as possible, came through in good condition.

### COMPARISON OF SEASONAL HISTORY IN SICILY AND NEW ENGLAND.

The spring of 1911 was cold, rainy, and rather backward in Sicily. By May 15, however, parasite maggots had begun to issue from the gipsy-moth larvæ. The earliest record for issuance of maggots for New England is May 22. It is likely that during many seasons in Sicily maggots issue by May 7, whereas the New England record referred to is an early one, issuance of maggots usually beginning the last of May. This would make the season in Sicily about three weeks earlier than at Melrose Highlands, Mass. The second-generation cocoons were being collected in Sicily by June 10, 1911, but June 23 is the earliest record of the presence of this generation in New England.

### ABUNDANCE OF A. MELANOSCELUS IN SICILY.

The parasite cocoons were very abundant in places as indicated in notes and correspondence received from Mr. Fiske.

Apanteles killed more caterpillars than all of the other parasites put together. Cocoons average 1,000 to a tree, not counting the smaller trees.

Notes made at another place state:

Apanteles exceedingly common. Estimate 75 per cent control on average and higher in some places. Estimate 10,000 cocoons on one large tree.

To illustrate the abundance of cocoons, those present on an area the size of a man's hand were counted and the number found was 187. Mr. Fiske states that there were more over a similar area high up on the tree. The same day he visited another place and found conditions similar.

### SECONDARY PARASITISM IN SICILY.

Apparently the first-generation cocoons are not attacked seriously by secondaries, probably less than 10 per cent being killed. Secondary parasitism of the hibernating cocoons is very heavy, and one note was found referring to a location where it was feared that it would almost exterminate the parasite. Sometimes as high as 75 per cent of the cocoons from Sicily received at the laboratory and wintered were killed by secondaries.

### COLONIZATION IN NEW ENGLAND.

During the rush of the season's work it was supposed that two or three species of Apanteles were represented and the importation and colonizations were recorded in correspondence and in the notes as *A. solitarius* and Apanteles II and III. The confusion was not at all surprising for there were two and possibly three species represented, but the fact of the matter, as it appears at the present time, is that the adults liberated during June, 1911, at North Saugus, Mass., from cocoons imported from Sicily as *A. solitarius*, were adults of the first generation of *A. melanoscelus;* and that the cocoons received later in the summers of 1911 and 1912, which were hibernated at the laboratory, and the adults from which were liberated at Melrose during the springs of 1912 and 1913, were cocoons of the second generation of *A. melanoscelus*.

During June, 1911, about 125,000 cocoons of the first generation were received from Europe, and every precaution was taken to prevent the escape of any secondaries which might be present. As soon as they were received at the laboratory they were taken to North Saugus, Mass., and immediately placed in darkened containers from which nothing could escape except by entering glass tubes, where they were inspected, the good allowed to escape and the bad destroyed. In this manner 23,000 adults were liberated during June and July, 1911. During the months of July and August, 1911, nearly 17,000 hiberating cocoons were received. These were isolated at the Melrose Highlands laboratory, each one being placed in a small gelatin capsule and then wintered under outdoor conditions.

During the spring of 1912 the adults which issued from these cocoons were liberated near the laboratory.

Early in 1912 Mr. Fiske again went to Italy, this time with several assistants. As one of the results of this trip, 22,000 cocoons of the second generation of *A. melanoscelus* were received during the summer of 1912. These cocoons were collected in the forest of San Pietro, near Caltagirone, Sicily, during the week beginning June 15. They were shipped to Naples in cold storage on June 22 and held there in cold storage until all had been isolated in gelatin capsules. Early in July they were sent to America in cold storage and hibernated at the laboratory. The adults which issued in the spring of 1913 were liberated at Melrose.

Table 1 shows the number of individuals of *A. melanoscelus* that have been liberated in New England. The colonizations of 1911, 1912, and 1913 were adults which issued from cocoons received from Sicily; the rest of the colonization material was obtained by rearing and breeding New England material.

TABLE 1.—*Number of A. melanoscelus liberated in New England, 1911–1920.*

| Year. | Number of adults liberated, Sicilian material. | Cocoons colonized, New England material. | Number of colonies placed in Massachusetts. | Number of colonies placed in New Hampshire. | Number of colonies placed in Rhode Island. | Total number of colonies. |
|---|---|---|---|---|---|---|
| 1911 | 23,000 | | 1 | | | 1 |
| 1912 | 203 | | 1 | | | 1 |
| 1913 | 273 | | 1 | | | 1 |
| 1915 | | 1,500 | 2 | 1 | | 3 |
| 1916 | | 5,541 | 11 | | | 11 |
| 1917 | | 3,500 | 7 | | | 7 |
| 1918 | | 8,100 | 9 | 7 | | 16 |
| 1919 | | 930 | 2 | | | 2 |
| 1920 | | 10,100 | 11 | 9 | 1 | 21 |
| Total | 23,476 | 29,671 | 45 | 17 | 1 | 63 |

As will be seen from a study of the figures in Table 1, very few adults were liberated in 1912 from the 17,000 cocoons received in 1911, and in 1913 from the 22,000 cocoons received in 1912. The poor issuance from these imported cocoons was due to several factors. Fifty to seventy-five per cent were killed by secondaries and a few were injured while being collected. These cocoons were kept in gelatin capsules from the middle of the summer until the adults issued the following spring. Subsequent experiments have shown that the mortality of hibernating larvæ of *Apanteles melanoscelus* was not so high when the cocoons were isolated in small glass vials plugged with cotton batting as when they were kept in gelatin capsules. An examination of dead maggots of *A. melanoscelus*, which had been isolated in gelatin capsules, showed that the maggots were

very dry and shriveled, and indicated that death might have been due to lack of moisture within the capsules.

No colonies were liberated in 1914, as no importations were made and the parasite had not been sufficiently well established to furnish colonization material.

All *Apanteles melanoscelus* liberated since 1913 have been put out while in the cocoon and have been of the summer-issuing generation. Most of these colonies have contained 500 cocoons. In liberating a colony the cocoons are taken to the field and emptied into a small cylindrical can, which is then nailed to a tree in an inconspicuous place. A cover is placed on the can to protect the cocoons from rain and birds. The adults escape through three ¼-inch holes punched in the can near the top. The size of the can is not especially important, but a convenient can used at the laboratory is 3 inches in height and 2 inches in diameter. It is necessary to place a band of tree-banding material entirely around the can to prevent ants from destroying the colony.

In selecting sites for colonies, woodland areas with a light to medium gipsy-moth infestation are preferable. Heavily infested territory which is apt to be stripped of its foliage should be avoided.

After the colony has been liberated a roadside tree is marked in white paint with an arrow pointing to the colony and the letters A. M. In the woodland near the exact spot of the colony a tree is banded with white paint. These field marks are made so that the place can be found later if desired. At the same time a numbered note is written for the laboratory files which explains the condition at the colony site and gives directions for finding the colony.

The colonies have been placed in groups of towns, one colony in each town, as shown in the accompanying map (Pl. IV). This method of liberating colonies was used because the parasite disperses rapidly and there was considerable chance that small colonies would not become established if they were placed singly at widely separated locations. In this way several rather large areas, from which the parasite can spread to the surrounding towns, have become well stocked.

### METHODS USED TO OBTAIN MATERIAL FOR COLONIZATION.

The story of the introduction of *A. melanoscelus* and the colonies liberated from the imported material has been recorded earlier in this paper. Two methods have been used to get material for colonization since the establishment of the parasite in New England—first, by rearing the parasite from field-collected gipsy-moth larvæ, and, second, by breeding the parasite at the laboratory.

The first method consists merely of making collections of large numbers of second-stage gipsy-moth larvæ from locations where the parasite is present in sufficient numbers to warrant such collections.

These larvæ are placed in trays and fed until the parasite maggots issue. The maggots, upon issuing, spin their cocoons, usually attached to the caterpillar or to the object on which the host was resting at time of issuance. Each day the gipsy-moth larvae are fed, the trays cleaned out, and all of the parasite cocoons removed. The cocoons are put up in lots of 500 and kept in a refrigerator until they are placed in the field. They are colonized as soon after removal from the trays as possible, usually on the following day. Occasionally it has been necessary to keep the cocoons in the ice chest five or six days, and this has been done without any apparent injury to the parasite.

The second method of securing material for colonization may be divided into two parts, namely, the fall work which consists of gathering and caring for the hibernating cocoons, and the actual breeding work which is carried on in the spring. There is a great mortality of wintering *A. melanoscelus*, largely due to secondary parasitism, and a large number of cocoons must be gathered in order to have a few adults of Apanteles in the spring to start the breeding work. The cocoons are collected as soon as possible after they have been found, in an endeavor to get them before the secondaries or ants do.

From 10,000 to 20,000 cocoons are collected during July from places where the parasite is abundant. Some of the secondaries present at this time hibernate within the cocoon, but there are many which have one or more generations during the early fall.

For a number of years these cocoons were isolated in gelatin capsules as soon as they arrived at the laboratory. This prevented the issuing secondaries from doing any further damage, but it was found that the spring issuance of *A. melanoscelus* from apparently good cocoons was exceedingly small. This was due partly to secondaries which hibernate within the cocoons, partly to injury while handling, and considerably to the drying of the maggots of *A. melanoscelus* in the cocoons. The last two years the cocoons have not been isolated, with the result that a better spring issuance has been obtained. Instead of isolating the cocoons they were separated into lots of 100 each and placed in glass tubes 1 by 4 inches, which were plugged with cotton batting. These tubes were then placed on a background of white in a warm bright place where they could be watched and the secondaries were removed as fast as they issued. Most of the secondaries issuing in the summer leave the cocoons within two weeks after collection, although a few continue to issue for two weeks longer. After the secondaries have stopped issuing the cocoons are picked over and the empty ones and those showing external injury are discarded. Many of the cocoons which contain hibernating secondaries at this time can be distinguished by a slight discolored spot on the cocoon; such cocoons also are destroyed. The

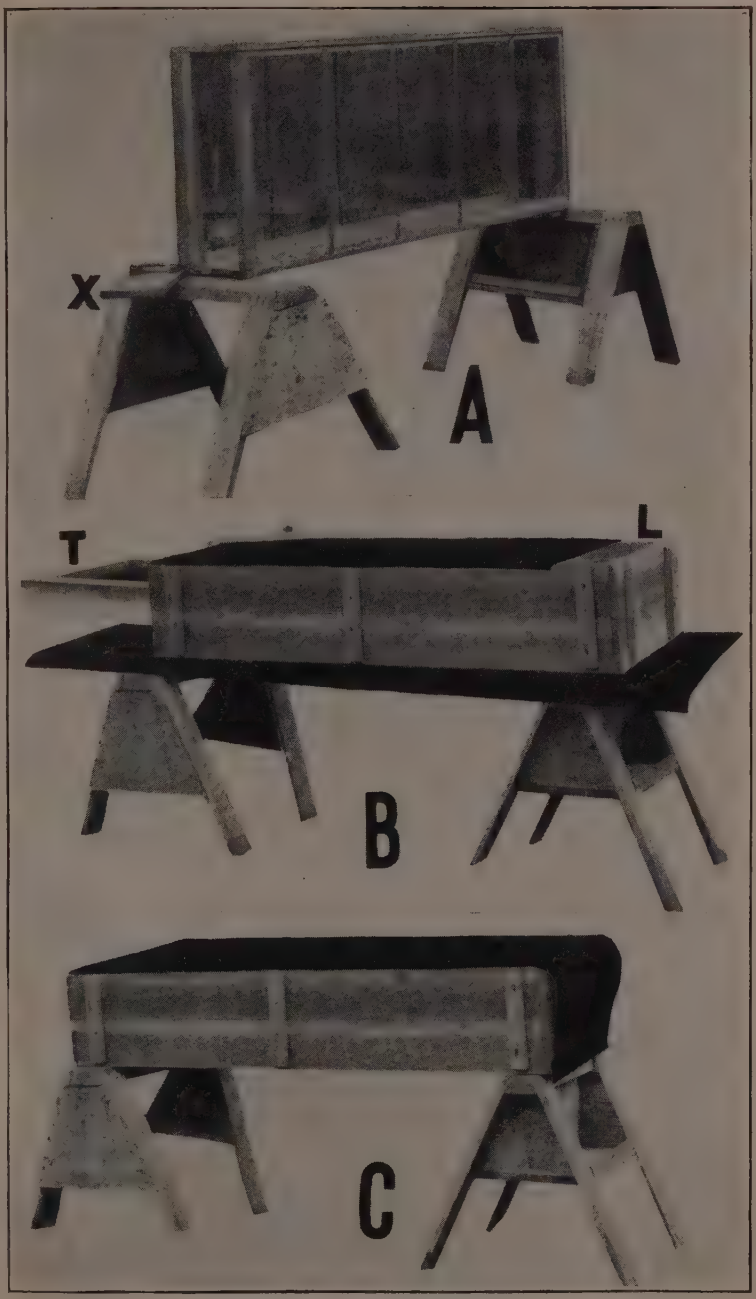
remaining cocoons are placed in bulk in a fine copper-wire cage which is nailed in a protected place in the yard until spring.

The spring work begins during the last of April when the cocoons are removed from their hibernating cage and isolated for a short period in capsules. They are isolated at this time for convenience in handling the adults of Apanteles and destroying the wintering secondaries which issue. The cocoons are isolated in the capsules less than two weeks before *A. melanoscelus* begins issuing, and this short period of confinement does not have a detrimental effect. As the adults emerge they are removed hourly from the capsules and placed in glass tubes 8 by 2 inches. The sexes are kept separate. A sponge dampened with a mixture of equal parts of honey and water is placed in each tube. The tubes are then placed in a cool, dark place until ready for use.

Several different types of cages and trays have been tried as breeding chambers with varying degrees of success. *A. melanoscelus*, like most hymenopterous parasites, is extremely heliotropic and individuals are found resting on the sides or top of the container or exhausting themselves flying about the source of light. During the past summer a breeding chamber was devised which eliminated the unsatisfactory light conditions of previous cages (Pl. V, A, B, C). This type of breeding chamber should prove of value in breeding work with other parasites.

The empty chamber is shown in Plate V, A, resting on one side. It is merely a wooden case with a glass bottom and top, with an opening left in one end, through which the tray containing the larvæ to be parasitized is admitted. The opening is just wide enough to allow the introduction of the tray and is about 2 inches deeper than the tray. Cleats on which the tray is to rest are arranged inside the chamber about 2 inches from the bottom. The tray should fit closely to the sides and ends of the chamber, but not tightly enough to bind when being introduced or removed. After the tray has been put in place the opening in the end of the cage is closed with a tightly fitting board (Pl. V, A at X).

When the chamber is to be stocked with the parasites it is placed on a flat surface which has previously been covered with black paper (Pl. V, B). A piece of black paper is laid over the top, covering all but 6 or 7 inches of the glass at the end of the chamber facing the sun (Pl. V, B at L). The parasites are liberated in the cage and fly to the uncovered part of the chamber where they gather on the glass top. The tray containing the small caterpillars is slid into place and is shown, part way in, in Plate V, B at T. The open end of the chamber is now closed and the whole thing is removed to two wooden horses, as shown in Plate V, C. A piece of black paper is now placed over the entire top.




APANTELES MELANOSCELUS.

*A*, Breeding chamber resting on its side; *x*, Board to close open end; *B*, Chamber ready to stock with parasites and gipsy-moth larvae. Tray containing gipsy-moth larvae shown at *t*, part way in; the light is admitted at *l*. *C*, chamber resting on horses, with light entering from bottom only.

With this arrangement all of the light entering the chamber comes from beneath, through the glass bottom of the chamber and through the cloth-covered bottom of the tray. Five minutes after the chamber is in this position practically all of the Apanteles have left the top of the chamber and are found dispersed over the bottom of the tray, where the gipsy-moth larvæ are feeding and crawling. The parasites begin ovipositing in the caterpillars immediately after they have been attracted to the bottom of the tray.

When the caterpillars have been exposed to *Apanteles melanoscelus* for a sufficient period the operations are reversed; the chamber is placed on a black-covered surface with the end of the chamber opposite the end where the tray is to be removed, facing the sun. Light is now admitted by removing the black paper over a space of 6 or 7 inches, as shown in Plate V, B at L. In a few minutes most of the parasites will congregate in the top of the chamber at the light end. The opposite end of the chamber can now be opened without danger of any of the parasites escaping. The tray is withdrawn slowly, care being taken that all of the Apanteles have left it. If any still remain, they will fly to the light end of the chamber when disturbed by touching them with a small camel's-hair brush.

As soon as the tray has been removed another one is introduced and the process is repeated as long as the supply of *Apanteles melanoscelus* lasts. The larvæ parasitized in this manner are fed in the trays until the parasite maggots issue. The resulting cocoons are removed each day for colonization.

A breeding chamber stocked with 300 adults of *Apanteles melanoscelus*, with the sexes equally divided, can be used about one week. Each tray should contain about 10,000 first-stage gipsy-moth larvæ.

The period of exposure of the larvæ to the parasites varies with the temperature and time of day. The parasites are most active during the middle of the day. The larvæ were enclosed in the chamber about two hours during this part of the day. Earlier in the morning and later in the afternoon the larvæ were exposed for about three hours. An average of about 1,000 parasite cocoons were removed from each tray. Undoubtedly many more than a thousand larvæ were parasitized in each tray, but there is always a certain amount of unavoidable mortality of first-stage larvæ in feeding trays. Many of the larvæ are weak and do not get to the food and many are injured when the trays are cleaned and the larvæ fed.

### SUCCESS OF COLONIES AND DISTRIBUTION OF A. MELANOSCELUS.

Records of the success or establishment of colonies liberated and of the distribution of the parasite are obtained by collecting host material from the field and rearing the parasite from these larvæ at the laboratory, or by collecting the cocoons of the parasite in the field.

Often the parasite is recovered the year following colonization. *A. melanoscelus* has been recovered from all but one of the colonies liberated previous to 1918. It has been recovered from half of the colonies put out in 1918 and from both of the colonies liberated in 1919. Recoveries of the parasite were made late in the summer of 1920 in a few of the towns which were colonized during June of that year.

### DISPERSION.

The inner black line on the map (Pl. IV) shows the present known distribution of the parasite in New England, it having been recovered from practically every town within this line. It is probable that in some cases *A. melanoscelus* has spread beyond the line indicated, for many of the towns just outside of the dispersion line have not been scouted.

It is rather difficult to determine the exact distance the parasite will spread in a year, for when the parasite is scarce its recovery is largely a matter of chance. The number of host larvæ which it is practical to collect in an endeavor to rear the parasite for dispersion records is infinitesimal when compared with the larvæ present in a town. Scouting for the cocoons is more satisfactory, but this is not infallible, and the fact that a town may have been scouted and no cocoons found does not prove that the parasite is not present.

The recovery records show that the greatest spread of this species has been to the north and northeast, similar to the dispersion of the gipsy and brown-tail moths. The data obtained indicate a spread of about 25 miles a year in this direction. During the summer of 1918 there were two recoveries made which because of their locations are of special interest. One of these recoveries was made at Provincetown, which is 25 miles northeast of Harwich, where the nearest colony of *A. melanoscelus* was liberated in 1915. The other recovery was made on the island of Nantucket, which is 25 miles south of the Harwich colony. In 1915 a colony of *A. melanoscelus* was liberated in Middleboro, about 33 miles southwest of Provincetown. The colonies at Harwich and Middleboro were the only ones that had been liberated in that part of the State. These recovery records can not be taken as absolute proof of a flight of 25 miles for the insect, as it is possible that cocoons of the parasite were taken to Provincetown and Nantucket on cordwood or other material. This does not seem likely, however, for the parasite was not recovered from any of the other towns in southeastern Massachusetts until 1919. The number of cocoons taken at Provincetown and Nantucket in 1918 indicated that the parasite had been present in both places for 1 year at least.

### SECONDARY PARASITISM.

Cocoons of the first generation are not seriously attacked by secondary insects. Small collections of cocoons of this generation are made each year over a considerable area and rarely are they parasitized over 10 per cent; more often not more than 2 or 3 per cent are killed by secondaries.

Unfortunately it is a different story with the hibernating brood, for approximately 75 per cent are killed annually by native secondary insects and ants. This seriously handicaps the increase of *A. melanoscelus*. Among the insects which have been reared from the hibernating cocoons are at least three Ichneumonidae, and members of the Pteromalidae, Elasmidae, Eurytomidae, Entedontidae, and Eupelmidae. In this complex there are secondary, tertiary, and possibly quaternary and quinquenary insects. An investigation of the life histories and host relationships of these insects has received considerable attention at the laboratory, but has not been completed. Some of these insects have several generations during the early fall and then hibernate within the cocoons of *A. melanoscelus*.

### THE VALUE OF A. MELANOSCELUS AS A GIPSY MOTH PARASITE.

The problem of obtaining the actual percentage of parasitism of the gipsy moth by *A. melanoscelus* or by any of the other introduced parasites, except the egg parasites, is a difficult and complicated matter involving many factors. Records at the Gipsy Moth Laboratory show that larvæ picked promiscuously from tree trunks and foliage to-day may give 30 per cent parasitism, while to-morrow the same number of larvæ, collected by the same individual, in the same manner, and in the same locality, may not even show the presence of the parasite.

For a number of years collections of gipsy-moth larvæ have been made daily through the entire larval period at Melrose and Stoneham, in an attempt to learn the true status of the parasites in that section. Each collection contained 100 larvæ all of the same stage. The collections of each stage were continued as long as that particular stage could be found, and collections of the next stage were started as soon as 100 larvæ of the next stage could be found. As there is quite an overlapping of stages, there were very often two collections on the same date at the same place. All of the collections were kept separate and the larvæ were fed in trays until all of the parasites had issued. The trays were examined each day and any parasites which issued were removed and recorded. Individual collections, containing 100 caterpillars each, gave from nothing to as high as 40 per cent parasitism of second-stage gipsy-moth larvæ for the spring

generation of the parasite. The records of parasitism secured from fourth-stage caterpillars which represent the second or summer generation of *A. melanoscelus* were about the same.

The second and fourth stages of the gipsy-moth larvæ usually showed the highest percentage of parasitism, but a considerable number of the individuals of the other stages were killed by the parasite. Occasionally collections were made which gave as high as 15 per cent parasitism, for each of the other larval stages. In large collections of larvæ where all the caterpillars in sight were collected, the parasitism obtained averaged around 10 per cent for each generation. The collections from which these figures were secured contained from 5,000 to 20,000 larvæ.

The figures obtained from the foregoing collections should not be taken as representing the value of the parasite.

There are a great many parasitized gipsy-moth larvæ which die in the field before the parasite maggot has had time to develop. The parasitized larvæ do not eat so much as nonparasitized larvæ and are inclined to crawl to out-of-the-way places and often are not seen by the collector. On the other hand, if one should search for the hidden larvæ the collection would not be representative of conditions as they truly exist.

There is each year a high percentage of mortality of the gipsy moth, which occurs whether insect parasites are present or not. This mortality varies from year to year depending upon the conditions which influence the contributing factors, but the average percentage of mortality (barring insect parasites) for any period of years is the same as for any other similar period of years, if the periods include a sufficient number of years to make the average a fair one. This average mortality is not sufficient to prevent the increase of the gipsy moth, nor is the parasitism by *A. melanoscelus* great enough to prevent the increase of this pest. Although the exact percentage of parasitism of the gipsy moth by this parasite can not be stated, it is evident that it has a very important place as a part of the sequence of parasites which in conjunction with the other natural agencies retards the increase of this injurious insect.

### ABUNDANCE OF A. MELANOSCELUS IN NEW ENGLAND.

*Apanteles melanoscelus*, like some of the other introduced parasites of the gipsy moth, is found abundantly in rather small areas. Each year since the parasite has been established these areas of abundance have been found more often and over considerably more territory. Until the summer of 1916 the parasite was not found in any appreciable numbers excepting at local points in and around Melrose Highlands. During the summer of that year a location at Beverly, Mass., was found where *A. melanoscelus* was very common. During the

same summer some interesting data were obtained from a medium-sized oak tree near the Gipsy Moth Laboratory at Melrose Highlands. This tree had many gipsy-moth egg clusters on it which had not been creosoted during the winter, so that on this particular tree there was a much heavier infestation of gipsy-moth larvæ than on any of the other trees in the vicinity. As the summer progressed, cocoons of *A. melanoscelus* began to appear in surprisingly large numbers. When most of the first-generation maggots had issued and spun their cocoons, the underside of nearly every crotch on the tree was covered with Apanteles cocoons (Pl. II, C).

There were 5,140 first-generation cocoons collected from this tree. A few cocoons could not be reached and some had blown away before the collection was made. Later in the season 511 second-generation cocoons were taken from the tree, making a total of 5,651 cocoons of *A. melanoscelus* removed from this tree. Although heavily infested the foliage on the tree was not damaged much by the feeding of the gipsy moth larvæ and very few gipsy-moth pupæ were found on the tree. These data are not given as a sample of the condition of the trees in Melrose Highlands in 1916, but the figures are interesting and show what happens under some conditions. Occasionally large oak trees have been seen in other towns on which it was estimated there were from 6,000 to 10,000 cocoons.

In 1918 this parasite was found in large numbers over an area of several acres of woodland in Cohasset. In 1919 and 1920 it was found abundantly in small areas in Hampton, N. H., and in the following towns in Massachusetts: Beverly, Quincy, Weymouth, Cohasset, Scituate, Marshfield, and West Boylston.

## CONCLUSION.

*Apanteles melanoscelus* has been present in New England since 1911 and is now firmly established. It is spreading rapidly from the colonies which have been liberated and is increasing in spite of its being heavily parasitized by secondaries.

The fact that *A. melanoscelus* is able to complete its life cycle on several native insects adds considerably to its value as an introduced parasite and makes its permanent establishment more certain than if the gipsy moth were its only host.

This parasite has two generations each year on the gipsy moth and is very abundant in many small areas. It gives promise of becoming one of the most valuable of the imported parasites.

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